



Innovation, Competitiveness, and Growth: Korean Experiences

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Korea has transformed itself from a stagnant agrarian society into one of the most dynamic industrial economies of the world within four decades. In the early 1960s when Korea first launched its industrialization efforts, it was a typical poor developing country with poor resource and production base, small domestic market, and a large population. Korea's GNP in 1961 was only \$ 2.3 billion (in 1980 prices) or \$87 per capita which came mainly from the primary sectors.² The manufacturing sector's share in GNP remained at a mere 15%. International trade was also at a very infant stage: in 1961, Korea's export volume was only \$55 million and imports \$390 million. But it is now 13th largest economy and one of the major trading countries of the world. It has also established world prominence in such technology areas as semi-conductors, LCD, telecommunication equipment, automobiles, shipbuilding, and so on. Indeed, it has emerged from nowhere as one of the key international players in the global economy.

Some say that in three decades, Korea has achieved what it took more than a century for the Western industrial countries to accomplish. There exist rich literatures on Korean growth that attribute the Korean success to an assortment of diverse factors. But many seem to agree that Korean government's "outward-looking development strategy," well-educated and well-

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² Korea is a very small, resource-poor country: its land area is only 220 thousand square kilometers or 99 thousand square kilometers if we exclude the northern part, which is currently under a different political and economic system. Korea's land, of which 75% is non-arable mountains, produces not a single drop of oil and contains virtually no valuable natural resources. Still it has to support a population of 70 million people.

disciplined work force, and technological innovation have been well combined to bring about what they call “Korean Miracle.”

Of the three factors, this paper focuses on the role of technological innovation. If technological innovation was the key factor, one may ask: What stimulated and facilitated Korean industries to engage so actively in R&D and innovation; and to what extent technological innovation has contributed to improving the competitiveness of Korean industries and to the growth of the economy. This paper discusses these issues, with a view to drawing some lessons from the Korean development experiences. Toward this end, this paper start with a review of what Korea has done to learn and acquire technologies for industrialization, and how Korea has been able to promote R&D and innovation and build up technological capability. And then we analyze the contribution of R&D and innovation to industrial competitiveness and economic growth in Korea. Finally, we draw some lessons for late-comers from the Korean experiences.

How Korea Learned and Acquired Technologies for Industrialization?

Back in the 1960s, Korea was no more than a barren land, so far as science and technology was concerned. There were only two public institutions for scientific research and technological development: the National Defense R&D Institute created right after the end of the Korean War, and the Korea Atomic Energy Research Institute which was founded in 1959, and less than 5,000 research scientists and engineers.³ In 1963, R&D expenditures remained at \$9.5 million.

Fortunately, however, Korea had well-educated workforce. Years of schooling of the workforce of Korea was as high as 4.98 in 1960 and school enrollment rate reached 100% for elementary education as early as in 1970. Indeed, Korea’s educational achievements stood fairly close to the level expected for a country twice as wealthy as it was.(Cohen and Soto, 2001) For this, Korea owes much to the Confucian tradition that places highest esteem on

³ The number here is an estimate based on the figure for 1969, which was 5,337 (MOST 1984)

education and scholarship.⁴

Under such a setting, Korea launched the First Five-Year Economic Development Plan in 1962, which along with the subsequent plans generated huge demand for new technologies. As Korea lacked in technological capability, it had to rely almost completely on foreign sources for technologies. Korea's policy strategy was geared to promoting the inward transfer of foreign technologies, while, at the same time, developing domestic absorptive capacity to digest, assimilate and improve upon the transferred technologies.

Korean Strategy for Technology Learning

Foreign direct investment (FDI) is often cited as a key to technological learning. Actually, FDI is considered by many to be the most effective means for late-comers to learn new production skills and acquire management expertise. But that was not the case in Korea. The Korean government took a policy that restricted FDI in various ways, say, ownership restriction, repatriation restriction, technology transfer requirement, export requirement, etc. Such a restrictive policy was inevitable because of the public sentiment in those days that viewed multinationals as promoting the perpetuation of economic and technological dependence, reinforcing the asymmetrical relationship between the industrialized and the developing countries. (Koo 1984; Vernon 1977; Stewart 1978)⁵ So, unlike in other developing countries, FDI played less important a role in Korea as a source of capital and technology.

Technology purchase through foreign licensing (FL) was also of modest importance in Korea because of the foreign exchange control of the government. Being a typical agrarian economy relying on agriculture for almost three quarters of the national production, Korea, in

⁴ However, the Confucianism may have adverse effects on the development of science and technology in Korea: it stresses patriotism and demands loyalty to the traditional values and, therefore, tends to devalue new, unconventional ideas. The Korean society, like other Confucian societies, is less open to different ideas and systems, which works as a barrier to innovation.

⁵ Foreign investors also did not view Korea as an attractive place for investment. Even though Korea took a very open and liberal policy on direct foreign investment in the 1960s, few investments were made primarily because of

the 1960s, simply could not afford to buy technologies from foreign sources. It is quite understandable that a country with a per capita GNP of \$ 87 (1962) and annual export revenue of only \$ 55 million (1962) took such a restrictive policy on FL which very often entails long-term financial commitment.

As an alternative, Korea opted for long-term foreign loans to finance industrial investments. The Korean government brought in large-scale foreign loans and allocated them for investments in selected industries, which led to massive importation of foreign capital goods and turn-key plants. Industries later reverse-engineered imported capital goods for the purpose of acquiring necessary technologies. This policy contributed to the formation of a unique business conglomerate called “Chaebol.” The government selected not only the target industries for investment but also the entrepreneurs who would actually implement the new investment projects, and some of those selected entrepreneurs later became owners of the “Chaebols.” So, we can say that the FDI policy has much to do with the evolution of the unique industrial structure of Korea.

How Private Industries Responded?

Private companies’ responses to such restrictive policies varied across industries. In the case of such light industries as shoes, clothing, textiles, and some intermediate goods for import substitution as well as export, the major sources of technological learning were OEM (original equipment manufacturing) production arrangements. Korean firms benefited most from the OEM production arrangements because they offered opportunities to work with foreign buyers who provided everything from product designs and materials to quality control at the end of the production. This was especially so in the case of garment and electronic industries. (Hobday 1995)

Turning into the 1970s, Korea’s development target was shifted to more capital- and technology-intensive industries, and they implemented massive investment projects to build up machinery and chemical industries. For the development of chemical industries, Korea relied

the questions about Korea’s political stability and economic outlook.

largely upon turn-key plant importation, which included technical training programs as part of the packages. In the case of heavy machinery, FL was an important channel for technology acquisition. (Chung and Branscomb 1996) To help industries adopt new technologies, the government created GRIs in the fields of heavy machinery and chemicals, such as the Korea Institute of Machinery and Metals (KIMM), the Electronics and Telecommunications Research Institute (ETRI), the Korea Research Institute of Chemical Technology (KRICT), the Korea Research Institute of Standards and Science (KRISS), the Korea Institute for Energy Research (KIER), the Korea Ocean R&D Institute (KORDI), etc. These institutes worked with private industries in building technological foundation for industrial development.

As a result, FDI had minimal impact on the Korean economy. For example, FDI accounted for only 3.9% of the cumulative total of long-term foreign capital in Korea over the period of 1962-1982 (\$ 9 billion). According to a United Nations report, FDI in all developing countries in the early and mid-1970s accounted for 10-20% of their total foreign capital inflow. Over the period of 1962-1972, FDI inflow in Korea remained at \$ 223 million, while capital goods import reached \$ 2,857 million. (Ahn 1991)

In short, Korean industries depended more on informal channels for technology acquisition than formal channels. As informal channels involve less market mediation and more active roles of technology recipients, they are less costly but require higher capability of technology recipients in not just identifying and selecting technologies but also absorbing, assimilating and improving upon the transferred technologies.⁶ This means that Korea has been able to succeed in acquiring technologies for industrialization largely owing to the rich pool of well-educated people who are determined to work for the betterment of their lives.

Building-up a Base for R&D and Innovation

While promoting technological learning for industrialization, the Korean government also made efforts to build up a base for S&T development during this period. The Science and

⁶ For more discussions on the roles of technology suppliers and recipients in different modes of technology transfer, see Kim (1997) pp. 100-103.

Technology Promotion Act and the Science Education Act were enacted in 1967 as a legal base for government's policies for S&T development. In the same year, the government established the Korea Institute of Science and Technology (KIST), and in the following year, the Ministry of Science and Technology (MOST) was created as the central government agency responsible for S&T policy. In 1970, the government enacted the Korea Advanced Institute of Sciences Act, on the basis of which the Korea Advanced Institute of Sciences (KAIS; currently KAIST) was founded. KIST was the first organization in Korea for R&D in a strict sense, while KAIS first brought US graduate education system into Korea. It was also in the 1970s that various GRIs were established to assist industries in absorbing and assimilating technologies. In the early stage of the development, these institutions did two important contributions: first, as mentioned earlier, they helped industries acquire new technologies, and second, they contributed to the building up of indigenous R&D capability by bringing back many established scientists and engineers from abroad.

Costs and Benefits of the Korean Strategy

In sum, the industrialization of Korea in the early phase was a process of learning how to absorb and improve upon imported foreign technologies for industrial development. Technological learning, as opposed to indigenous technology development, was in the core of the development strategy in the early stage. The results of such efforts were amazing. Around the end of the 1970s, Korea's top 20 export items included ships, semi-conductors, TV sets, radio cassette, and so on.

The Korean approach to technology acquisition resulted in both positive and negative effects. On the positive side, this policy enabled Korea to acquire technologies at lower costs, and precluded the constraints often imposed by multinationals on local firms' efforts to develop their own capability. The approach was effective in maintaining independence from the dominance of multinationals. Negative effect is that Korea had to give up an important access to new technologies that might have been available through direct equity links with foreign firms. By restricting FDI, Korea failed to adopt global standards in domestic business

operation.⁷ The most important lesson here is that had it not been for the well-educated work force, it would not have been possible for Korea to succeed in acquiring and utilizing technologies through informal modes of technology transfer.

Table 1 Foreign Technology Transfer to Korea, 1962–81
(\$ millions)

	FDI	FL	Capital Goods
1962-66	45.4	0.8	316
1967-71	218.6	16.3	2,541
1972-76	879.4	96.6	8,841
1977-81	720.6	451.4	27,978

Source: National Statistical Office

How Korea Has Been Able to Build up Indigenous R&D Capability?

As industrial development continued into the 1980s, the technological requirements of Korean industries became more complex and sophisticated. At the same time, it became increasingly difficult for Korea to acquire technologies through informal channels. Even though the government loosened its regulation of FDI and liberalized FL, it did not result in significant increases in FDI inflow and FL. The government viewed this as a signal that to sustain the development, it is imperative to build indigenous R&D capability. The government launched the National R&D Program in 1982 and took various policy measures to promote and facilitate private R&D activities.

From Technology Learning to Technology Development

Private industries responded to the changing environments by investing in R&D in a

⁷ Another negative effect is that large-scale loans that had been brought in instead of FDI might have contributed to the financial crisis of 1997 (Chung and Suh 2005)

massive way. As a result, the relationship between technology imports and R&D changed. The ratio of technology imports to business R&D declined sharply from about 90% in 1975 to 30% in the mid-1980s.⁸ This implies that by that time Korean industries turned to indigenous R&D for technology acquisition. R&D investment has since undergone a quantum jump. Korea's R&D investment, which stood at only 368.8 billion Won (\$526 million, 0.81 % GDP) in 1981, rose to 10,878 billion Won (\$13.5 billion, 2.8% of GNP) in 1996, to 13,848 billion Won (\$12.2 billion, 2.7% of GDP) in 2000, and to 31,301.4 billion Won (\$33.7 billion, 3.47% of GDP) in 2007. Over a period of twenty-five years, investment in R&D increased over sixty times. Korea invests in R&D a lot more of its income than others with the same or higher income. Korea now is the 6th largest spender in R&D among OECD countries.

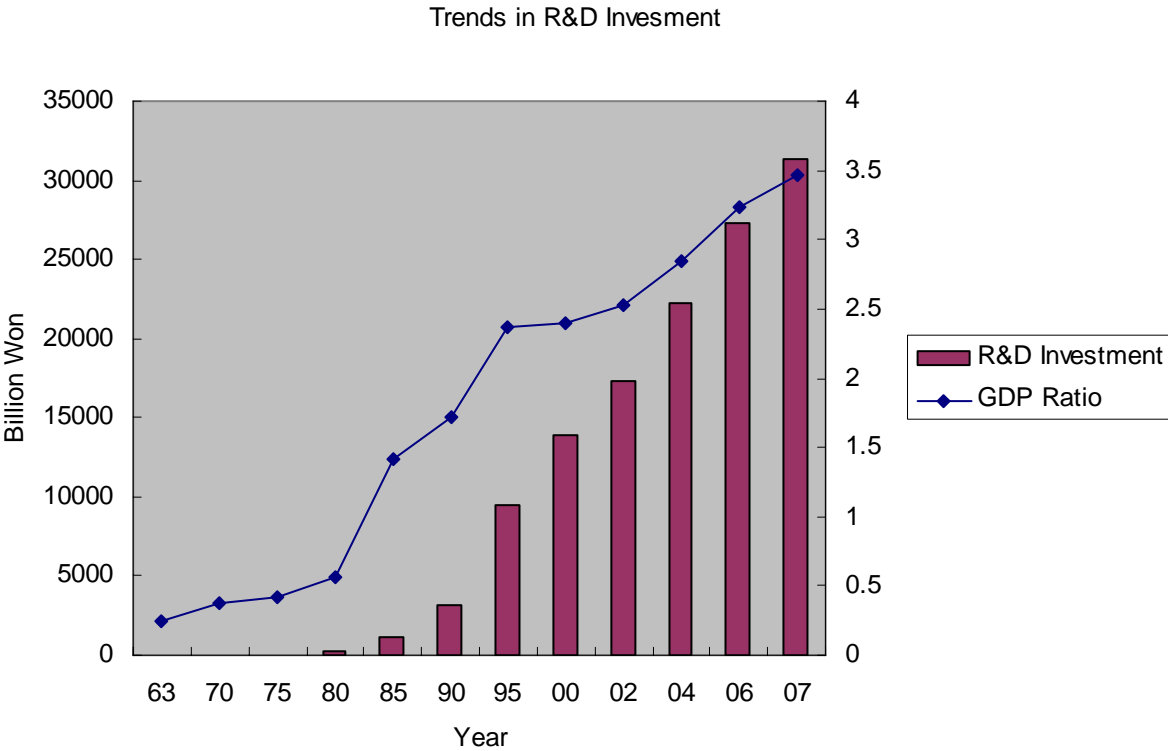


Figure 1 Trend of R&D Investments: 1963-2007

⁸ OECD (1996) pp. 91-92; Ratio of technology imports to business R&D was 15% in 2007. (KOITA 2008)

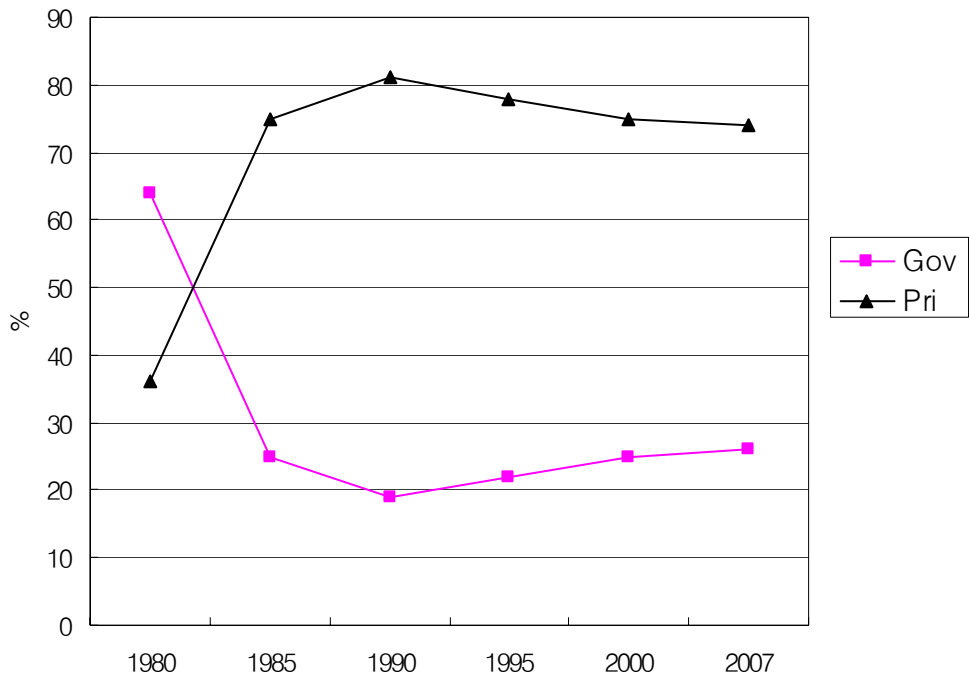


Figure 2 Changes in the Shares of Government and Industries in Total R&D Expenditures

Private Industries Took the Lead in R&D and Innovation

Private industries account for about 75% of the nation’s gross R&D expenditures in Korea. This means that private industries are the dominant players in R&D in Korea. In 1980, there were only 321 industrial R&D labs with 5,100 researchers, of whom only 56 were Ph.D. degree holders. After 27 years, the number of industrial R&D labs grew to almost 14,975, employing over 190,000 researchers, including about 10,000 Ph.D. degree holders. (KITA 2007)

Of the total industrial R&D expenditures in 2007, manufacturing industries took up about 90%. Manufacturing R&D is largely led by electronic equipment (including office equipment, electronic components, and communication equipment: 49.2%), automobiles (17.9%), and chemicals (11.2%). So, electronic equipment, automobiles, and chemical industries explain almost 80% of the manufacturing R&D, suggesting a very high concentration of manufacturing

R&D in a few industries.

The average R&D intensity of Korean industries was 2.43% in 2007, and that of manufacturing industries was 2.97%. The industries that invested largest shares of their sales in R&D include medical and precision equipment (7.5%), communication equipment (6.71%), and electronic components (6.33%). In contrast, constructions, pulp and paper industries, food and beverages, textile industries invested less than 1% of their sales in R&D. (Table 2)

Quite naturally, industrial research is very much focused on development (72%) and applied research (12.6%) with the remaining 12.6% devoted to basic research. Of the total industrial R&D, 80% were for new product development, while only 20% were for the improvement or development of processes.

Industrial R&D activities in Korea are highly concentrated in large enterprises. Twenty largest companies account for 55.73% of the total manufacturing R&D, top ten companies 50.2%, and top five companies 44.3%. In the case of electronic components, top 20 companies' share is 91.4%. (Table 3) The extremely high concentration of industrial R&D is a direct reflection of the large-firm oriented industrial structure of Korea. Top five companies in R&D investments are Samsung Electronics, LG Electronics, Hyundai Motors, Hynix, and GM Daewoo Auto and Technology, all of which are Chaebol companies.

Another unique feature is that the participation of foreign funds and institutions in R&D and innovation in Korea is very limited. Probably due to the once restrictive FDI policy, foreign funds seldom flow into Korea for industrial R&D. The proportion of foreign funds in Korea's industrial R&D expenditures remains at 0.3%, while in many of the OECD countries, foreign funds accounts for more than 10% of the domestic industrial R&D outlays. (OECD MSTI, OECD STI Scoreboard) Considering the fact that Korea is one of the major trading countries in the world, it is rather against expectation that Korea's international interaction in research and technology remains at such a level.

Recovery from the Damages of Financial Crisis of 1997

R&D in Korea had been growing rapidly and continuously until Korea was hit by the financial crisis in 1997. R&D was one of the most damaged victims of the crisis. Actually, industrial R&D expenditures decreased by 10% in a nominal term from 884.4 billion Won in

Table 2 Manufacturing R&D, 2007

Industry	R&D expenditures (billion won)	R&D intensity (%)
Total	21,339	2.97
Food	331	0.76
Textile	146	0.86
Pulp, paper	40	0.71
Chemicals	2,399	1.49
Non-metal minerals	142	1.20
Basic metals	171	0.63
Fabricated metals	75	1.92
Machinery	1,617	3.56
Office equipment	343	4.29
Electro components	7,624	6.33
Communication equipment	2,886	6.71
Medical and precision equipment	205	7.50
Automobiles	3,831	3.42
Others	56	1.39

Source: KOITA (2008)

Table 3 R&D Concentration in Manufacturing, 2007 (%)

	Top 5	Top 10	Top 20
Manufacturing	44.3	50.2	55.7
Chemicals	21.9	32.4	45.9
Electro components	85.7	89.5	91.4
Communication equip	64.9	69.4	73.1
Automobiles	67.6-	76.4	88.3

Source: KOITA (2008)

1997 to 797.2 billion Won in 1998 and R&D personnel by 15% from 102 thousand in 1997 to 87 thousand in the next year. This was a serious blow to the Korean innovation system. If the crisis had continued several more years, the Korean innovation system would have collapsed. Fortunately, however, Korea recovered from the crisis in a relatively short period of time: it took only two years for the industrial R&D to recover and rise over the level prior to the

financial crisis. There are two factors behind this development: one is the government's efforts to make up for the decrease in industrial R&D expenditures by increasing government R&D expenditures. The share of government in the gross R&D expenditures increased from less than 20% before the crisis to 27% after the crisis. Government R&D funds flew into private industrial sectors, in particular, small technology-based firms and helped them maintain and expand innovation activities. The other is the promotion of IT and IT-related ventures that led to an IT boom in the early 2000s. The government's commitment to IT development is well reflected in the fact that the share of IT in government R&D expenditures rose to 33.5% in 2002 from 13% in 1997. Such a pro-IT policy fuelled innovation in IT sector, which then affected innovation activities in other sectors. This policy not just helped the Korean innovation system recover vitality but also resulted in promoting Korea's transition toward an information society.

What Are the Factors behind the Rapid Growth of R&D and Innovation?

There are many factors that have contributed to the rapid increases in private sector R&D investments. But the rapid growth in R&D expenditures can be explained by two sets of factors – demand factors and supply factors. On the demand side, market competition placed tremendous pressure on Korean industries for technological competitiveness. Such pressure generated continuous demand for R&D and innovation. On the supply side, Korean industries have been able to meet the increasing demand for R&D and innovation because they have been financially able to do so and also because their investments have been backed up by well-trained human resources. The government contributed to such a development in several indirect ways.

Competition best motivates R&D and innovation

First, the outward-looking development strategy (export-drive) of the government drove domestic industries out to international market, putting them under fierce competition. In order to survive the competition, they have had to keep up with technological changes by investing heavily in R&D.

Many studies have shown that the more international trade-oriented a company is, the more

it invests in R&D and innovation. A recent study at the Science and Technology Policy Institute (STEPI) has confirmed the relationship using the Korean Innovation Survey (KIS) data.⁹ The empirical study shows that companies with higher export intensity (export volume/total sales) tend to invest more in R&D and innovation. (Shin and others 2006) The study also found that there exists a negative relationship between innovation activities and market concentration. In other words, the study confirmed that companies operating in a more competitive market invest more in R&D and innovation. This study seems to say that international competition motivates companies to invest in innovation. But a reverse relationship may hold, too, as more innovative companies are more likely to win international competition and sell more in the international markets. In that sense, we can say that the two are mutually reinforcing and so the effects of one on the other are determined simultaneously.

Chaebols' role has been important

Second, on the supply side, the government's industrial policy that favored large firms gave birth to a unique business organization in Korea, "Chaebol," which is similar to "Zaibatsu" of Japan before WW II. Chaebols enjoy greater financial affluence owing to the economies of both scale and scope of their business operation. Regarding the behavior of Chaebol companies in terms of innovation, there are two conflicting arguments. One argues that in such a business structure, the major share holder may pursue his/her private interests at the cost of other share holders and is likely to seek short-term personal benefits rather than long-term benefits of the company. And therefore, under such structure, innovation may not be actively pursued. The other argument is that the business conglomerates like Chaebol may be able to reduce transaction costs through internal transactions. In addition, they argue that Chaebol companies can share risks, while, at the same time, pooling financial resources for major investment projects. Furthermore, under Chaebol system, decision-making process is highly centralized and,

⁹ The survey (KIS 2005) covers 2,737 companies of 23 industries for the period from 2002 to 2004. The survey follow the OECD Manual and has been authorized as a national statistics by the National Statistics Administration of Korea.

therefore, they can be quicker in responding to emerging opportunities.

There have been many attempts to verify the arguments, but there are only a few studies that directly investigate the differences in innovation behavior between companies belonging to Chaebols and independent companies. Recently, a group of researchers at STEPI conducted a research on this issue using the data-base of the Korea Information Service Inc covering 51,270 observations for the period of 1987-2003. (Shin and others 2006) Of the total observations, 2,064 are for Chaebol companies. The study divided the period into two – one before the financial crisis (1987-1997) and the other after the crisis (2000-2003), because the government changed the regulation governing the Chaebol system during the period of the economic crisis. The new regulation bans cross- financing and cross-investment between and among Chaebol companies, and, therefore, pooling financial resources and sharing financial risks between and among Chaebol companies have become impossible. In other words, the Chaebol in the original sense disappeared around the end of the 1990s.

The statistical analysis for the pre-crisis period shows that Chaebol companies are more able and more likely to invest in R&D than independent companies. But the analysis for the post-crisis period could not find any statistically significant differences in innovation behavior between Chaebol companies and independent companies. This supports the argument perception that Chaebol companies which are usually big international operators, have deeper pockets and are able to engage in risky and expensive R&D projects that are even unthinkable for small- and medium-sized firms.

Human resource was the key

Another supply factor is related to human resources. Korean industries have been able to increase R&D investments at such rapidity, thanks to the abundant pool of highly-educated manpower. Considering the fact that R&D investment is more constrained by the lack of human resources than financial limitation in both developed and developing countries, we can say that Korea prepared itself well for development by investing heavily in advance in education and

human resource development.¹⁰

Government support programs

No less important is the policy supports of the government for industrial R&D and innovation. In order to promote private innovation, the Korean government, like many others, offers various forms of incentives for industrial R&D and innovation.¹¹ Overall, Korea employs grants and tax credits as the major instruments to promote industrial R&D which are complemented by such support programs as procurement, technical consultancy, information, technology transfer and so on. According to a recent survey, there are currently more than 250 small and large programs to support private R&D and innovation. (Shin and others 2006)

How effective those programs have been in promoting industrial R&D is an issue of great concern. There have been a few attempts to evaluate the effectiveness of the policy programs.¹² In order to evaluate the policy programs, quantitative assessments on each of the programs is most desired. But full-scale quantitative analysis is not practically possible due to the lack of data. In 2006, STEPI undertook a survey of private industries to assess the effectiveness of the government incentive programs. Using the results of the survey and the Korean Innovation Survey (KIS 2005) data, they conducted econometric and statistical analyses. Interestingly, the survey results and the econometric analysis using the KIS data showed a very similar result that all categories of support programs have been effective in promoting private R&D and innovation except for the procurement program. The econometric analysis further found the tax incentive most effective, followed by loan program, human resource program, and technical consultancy and so on. This is also consistent with the OECD evaluation that “Tax incentives for R&D in Korea are generous and cover every stage: facility investment, R&D outlays,

¹⁰ There are cases where R&D investments are constrained by the shortage of suitable manpower. OECD (2003) emphasizes the importance of the supply of skilled scientists and engineers as one of the framework conditions for achieving R&D spending target.

¹¹ The major legal bases for the incentives are the Technology Development Promotion Law (1967) and the Industrial Development Promotion Law.

¹² For example, Lee and Jang (1998), Song(2007), and Shin(2006)

technology transfer...” (Bae and Jones 2005)¹³

What We Reaped from the Investments?

As to the performance of R&D and innovation activities in Korea, evaluations are mixed. Some have a negative view that Korea excels other countries in R&D inputs, say, human and financial inputs, but lags way behind in outputs. Others say that R&D results have not been effectively linked to industrial uses.

Despite such criticisms, one cannot deny the positive contributions that the R&D and innovation efforts have made. Rapid growth in R&D investment has led to a remarkable increase in patent registration. The number of KIPO (Korea Industrial Property Office) patents increased from 1,808 in 1981 to 123,705 in 2007, more than a seven times increase in 26 years.

Furthermore, Korea ranked 4th in the world in terms of the number of 2007 PCT (Patent Cooperation Treaty) applications, triadic patents registered in 2006, and 2007 US patents registered. In the production of industrial property, Korea trails only after the US, Japan and Germany. (KIPO, WIPO, OECD MSTI, USPTO) Of these, US patent is sometimes used as an indicator of international technological competitiveness of a nation. The number of US patents granted to Koreans was only five in 1969, but grew to 1,161 in 1995 and to 6,295 in 2007, putting Korea at the 4th place in the world. (See Table 4) A patent analysis by the US Department of Commerce in the late 1990s evaluated that Korea already established world prominence in such technology areas as information/telecommunication, pharmaceuticals, advanced materials, and automotive.¹⁴ The above statistics indicate that Korea has been rapidly gaining in technological competitiveness.

Another important development is the remarkable increase in the number of scientific publications in the internationally recognized academic journals. The number of scientific

made simpler and easier to¹³ Despite the overall effectiveness of the programs, the STEPI study assesses that the numerous and diverse programs are so well understood by the potential users and need to be access.(STEPI 2006)

¹⁴ Albert (1998)

publications by Koreans reported by the Science Citation Index (SCI) increased from a mere 171 in 1980, 5,390 in 1995, 23,099 in 2005, and 25,494 in 2007. Korea now is the 12th largest producer of SCI publications, which should be considered a phenomenal growth. (See Table 6)

R&D efforts have also contributed to the development of high-tech industries in Korea. Korea's technological competitiveness in semi-conductors, displays, cellular phones, computers, telecommunication equipments and so on are partly the results of the government-industry collaborative R&D. Considering the contribution of these technologies to the Korean exports and economic growth, we can get a rough idea on the relationship between R&D and innovation and the socio-economic changes in Korea.

Even though Korea acquired technological competitiveness in many of high-tech products, its reliance on foreign core technology has not been reduced in a substantial way. For example, Korea succeeded in commercializing the CDMA technology, but the Korean cellular phone manufacturers have had to pay a cumulative royalty of over 5 trillion Won to Qualcomm over the period from 1995 to 2008. (NSTC and KISTEP) So, Korea's overseas royalty payments are concentrated in the areas where Korea is known to have international competitiveness. It is simply because Korea's industrial R&D and innovation have been focused too much on commercializing foreign technologies rather than on developing new original technologies, such as new materials, components, devices or designs.

Table 4 Number of KIPO Patents Granted

	1981	1985	1990	1995	2000	2005	2007
Number of Patents	1,808	2,687	7,620	12,512	34,956	73,512	123,705

Source: KOITA

Table5 Number of US Patents Granted to Koreans

	1985	1990	1995	2000	2005	2007
Number	41	225	11,161	3,314	4,352	6,295

Rank in the world	-	9	-	-	7	4
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Source: USPTO

Table 6 Number of SCI Publications

	1980	1985	1993	1997	2000	2007
Number	171	1,227	2,997	9,124	12,245	25,494
Rank in the world	-	37	27	17	16	12

* Source: KOITA

How R&D and Innovation Have Been Linked to Industrial Competitiveness?

In a Neo-Schumpeterian sense, success in forging industrial competitiveness through innovation may imply a sustainable increase in the share in the market or in world trade. (Cantwell 2003) Based on this, we can assess the contribution of R&D and innovation to industrial competitiveness by examining how R&D and innovation affected the changes in commodity structure of exports, and the changes in shares of major export commodities in world trade.

Changes in Export Structure

As shown on Table 7, in the 1980s, Korea was engaged in trade of medium-low and low-tech commodities, and gradually moved toward higher technology commodities. Now, Korea's exports are highly concentrated on high-tech products, such as semi-conductors, telecommunication equipments, displays, and so on.¹⁵ The share of high-tech and high-medium-tech products in Korea's exports increased from 13.45% in 1980s to 43.2 in the 2000s. The drastic changes in the technological components of Korea's export products well explain the technological developments Korea has gone through over the past three decades or so.

¹⁵ We follow here the OECD categorization of high-tech, high-medium-tech, medium-low-tech, and low-tech.

Individual industry's contribution to exports has also changed drastically during the period from 1990 to 2007. In the case of the primary and light industries, their shares in the total exports have declined in a massive way. The primary industry's share has gone down from 4.9% to 1.5%, and textiles' share from 26.7% down to 3.7%. On the other hand, the shares of high-tech products have risen significantly during the period. In particular, precision machineries, telecommunication equipments, displays and automobiles account for almost 40% of the total exports of Korea. The highly concentrated export structure of Korea is a kind of reflection of the highly concentrated distribution of Korea's R&D expenditures and highly concentrated patents. Of the Korean patents registered in 2006 (KOITA 2008), electronics and communications took up 54.2% and machineries 15.0%, which is consistent with the data on Korean industrial R&D expenditures which are concentrated in a few industries such as telecommunications, transportation and so on. What is evident is that R&D-intensive industries have gained in their market shares, while low-R&D industries have lost their pace in the international markets. This is also confirmed by WTO data which show that Korea's world market share has been increased remarkably in technology-intensive products, such as office machineries, telecommunication equipments, automotive parts and chemicals. (WTO) Interestingly, in those areas, R&D investments have also increased significantly in Korea.¹⁶

Table 7 Top Ten Export Commodities: 1980 - 2007

Rank	1980	1990	2000	2007
1	Apparels	Apparels	Semi-conductor	Automobiles
2	Iron and steel	Semi-conductor	Automobiles	Semi-conductor
3	Ships	Shoes	Ships	Telecom equip

¹⁶ In the case of office machinery, the ratio of R&D expenditures to sales has increased from 4.74% to 6.05% in Korea during 1990-2007, contributing to the increase in its share in world trade from 2% in 1980 to 6.1% in 2007. More contrasting is the case of telecommunication equipments, where R&D intensity has also increased from 3.05% to 6.52% over the same period and this contributed to the change in its share in world trade from 0 in 1980 to 7.2% in 2007.

4	Synthetic fiber	Ships	Cell phones	Ships
5	Audio	Video	Synthetic fiber	Petroleum prod
6	Tire	Iron and steel	Auto parts	Displays
7	Wooden prod	Synthetic fiber	Display	Auto parts
8	Misc goods	Computers	Telecom equip	Computer
9	Semi-conductors	Audio	Computer	Visual inst
10	Video	Automobiles	Color TV	Electro parts

Source: Korea International Trade Association

Table 8 Changes in Industrial Shares in Korean Exports: 1990 - 2007

	Industries	Export share in 1990 (%)	Export share in 2007
Declining share in world trade	Primary industries	4.9	1.5
	Textiles	22.7	3.7
	Shoes	6.6	0.1
	Home appliances	11.3	3.7
Maintaining share in world trade	Steel and iron	6.7	6.2
	Computers	3.9	3.7
Increasing share in world trade	Petro-chemicals	2.0	7.8
	Automobiles	3.0	10.1
	Precision machineries	2.8	6.9
	Telecomm equipment	0.8	8.3
	Semi-conductor	7.0	10.6
	Flat displays	0.0	4.5
	Ships	4.3	6.5

Source: Rearranged from KITA

How Much R&D and Innovation Have Contributed to Economic Growth?

It is hard to estimate how much investments in R&D and innovation have contributed to economic growth, because it involves many complex data and methodological issues. One widely used method of measuring this was first suggested by Grilliches (1984) who calculated the growth rate of total factor productivity (TFP) and related this to the changes in R&D stock to measure the R&D elasticity of TFP. His estimates of R&D elasticity of TFP ranged between 0.17 and 0.34. Coe and Helpman (1995) conducted the same experiments using 22 OECD country data for the period of 1971-1990. They found that the elasticity for G-7 countries was 0.234, but the estimated elasticity for OECD countries was only 0.07, which suggests that R&D investments of G-7 countries were a lot more efficient than those of OECD countries.

Similar attempts have been made to measure the R&D elasticity of TFP in Korea. Kim (2004) estimated R&D elasticity of TFP in Korea for the period of 1970-2002 to be 0.13, while an earlier study by Shin (1996) came up with a higher number, 0.166. More recently, Shin and others (2007) estimated R&D elasticities of individual OECD countries and found that Japan is the most efficient (elasticity: 0.278-0.292) in terms of economic contribution of R&D, followed by the US (elasticity: 0.167-0.263), and Korea (elasticity: 0.133-0.199). The elasticity for Korea turned out to be almost the same as the average elasticity for all OECD countries (0.188). This suggests that R&D in Korea has performed relatively well in enhancing the productivity of the economy.

There is a very interesting study in Korea (Lee and others 2007) that estimated the R&D elasticity separately for high-tech, high-medium-tech, medium-low-tech, and low-tech industry. They found that R&D elasticity of TFP for high-tech industry was 0.32 and that for high-medium tech industry 0.10. But they found, interestingly, in medium-low-tech, and low-tech industries, TFP does not respond to changes in R&D stocks, that is, R&D does not affect the productivities in those industries.

Many economists use aggregate production function to estimate the contribution of R&D stock to economic growth. The results of estimations vary depending on the periods covered, data, and methods. A recent study (Lee 2008) in Korea estimates that R&D stock accounts for 22.7% of the economic growth during the period of 1971-1990. According

to the study, R&D stock's contribution to economic growth has been increasing along with economic development. The share of R&D stock in the economic growth during the period 1991-2006 was estimated to be 29.9%. But sometimes, study results vary too widely to reconcile. For example, according to Hah (2004), R&D stock explains 48% of the growth of TFP, while Bae and others (2006) came up with a result that the contribution of R&D stock to TFP growth amounts to 82% which is much higher than that suggested by Hah.

Table 9 Contribution to Economic Growth by Inputs

	1971-1980	1981-1990	1991-2000	2001-2006
Growth(%)	6.99	8.37	5.90	4.52
Labor(%)	2.47	1.95	1.10	1.05
Capital(%)	3.29	3.08	2.75	1.43
TFP(%)	1.23	3.34	2.05	2.04
R&D (%)	1.74		1.61	

Source: Lee (2008)

Achievements Korea Has Made and Challenges Ahead

What Korea Has Achieved

Korea has made enormous development in science and technology over the past four decades. By making continuous and massive investments in R&D and innovation, Korea succeeded in building up a unique Korean innovation system on a barren land, which will facilitate sustainable growth of the Korean economy. The factors that have influenced the Korean Innovation System (KIS) most are (1) outward-looking development strategy, (2) large-firm oriented industrial policy, and (3) human resources, among many others. These are also the sources of the strength and weakness of KIS.

The very strength of KIS is its dynamism that is fueled by the strong commitment of the

government to “technology-based national development” and private industries’ efforts for competitiveness. Despite the short history of R&D, Korea has already harvested rich crops from the endeavor in the forms of patents, scientific papers, and exports of technology-intensive products, such as semiconductors, cellular phones, LCD, automobiles, and others. These achievements have been the sources of growth in the past and will function as a base for further growth in the future.

But Challenges Are There, Too

Yet there are problems, too. R&D activities in Korea have grown very rapidly, led by private industries under active promotion policy of the government. Even though Korea spends a larger share of GDP on R&D than other countries, it still lags far behind advanced industrial countries in terms of the cumulative R&D stock which is really the determinant of a nation’s knowledge power. The challenge is how to overcome the disadvantage of being a late starter.

Second, the weakness in basic sciences poses a fundamental problem for KIS, because scientific capability determines the technological potential of a nation. Since the Korean R&D efforts have been devoted overly to industrial technology development, scientific research has been more or less neglected. The lack of strong scientific base already works as a limit to technological progress in Korea. The weakness in science as a matter of fact results not just from the funding policy that favors technology development but also from weak university research capability. Therefore, strengthening university research base poses one of the major policy challenges.

Third, excessive reliance on private industries for R&D investments has made the innovation system very vulnerable in two ways. On the one hand, the system places so much emphasis on applied research and development that it failed to build up a strong foundation required for the long-term development of science and technology. On the other hand, the R&D system responds too sensitively to changes in economic and business environments. For instance, large Korean enterprises responded to the financial crisis of 1997 by cutting their R&D spending by about 14 %, destabilizing the R&D system. If the crisis had continued for several more years, the whole system would have collapsed.

Fourth, the Korean innovation system needs to be made more open to the outer world. Korea accounts for about 3% of the world R&D activities, which means that 97% of the world's R&D activities are taking place outside Korea. In order to access to the new knowledge, ideas and technology generated and produced outside the country, Korea need to open the system more and promote interactions with foreign scientists and institutions. The current level of international interaction of Korea, which is the lowest among OECD countries, if not checked, will work as a barrier to further growth of Korea into the future.

Fifth, the extremely high concentration of R&D activities poses a serious problem. High concentration means that only a few large firms are actively involved in R&D, while others are not. If this persists for long, this will dichotomize Korean industries into technologically advanced and retarded firms and sectors. This will result in reducing inter-firm and inter-industry interactions that are the key elements of innovation. This is important because even Chaebol companies would not be able to sustain competitiveness without technologically strong domestic SMEs.

Any Lessons to Offer?

Korean experiences offer some lessons for policy-makers responsible for education, trade, and technology development of developing countries. There is no doubt that education builds a nation's ability to absorb new knowledge and technology. Education gives rise to individual's initial tacit knowledge, which is an essential building block in technological learning. So, the government should assume full responsibility for the promotion of human resource development. Investing in education in advance, as Korea did in the 1960s and 1970s, is essential in laying a foundation for industrial development. As an economy develops toward an advanced level, technological competence becomes a critical factor. To build up the competence, it is required to nurture high-caliber scientists and engineers who are capable of dealing with the developments at scientific and technological frontiers. In other words, advanced education in science and technology should come first in preparing for entrance into a developed world. In the case of Korea, education and industrialization helped each other in sustaining and accelerating mutual development. Education made technological learning and therefore industrialization possible, while industrialization enhanced the rate of return on

investment in education, further promoting demand for education.

Korea's industrialization evolved from imitation to innovation. In the initial stage, Korean industries attained technological capability through informal channels for technology transfer, such as OEM production arrangements, reverse engineering of imported machines, technical training as part of turn-key plant importation, and so on. Contrary to the experiences of other developing countries, FDI played a modest role in technological learning in the course of development in Korea. To lay the initial technological foundation, many Korean industries resorted to non-market processes, relying on the technological absorptive capacity of their workers for technology acquisition. This approach enabled them to acquire technology at lower cost and maintain independence in business operation. But Korea had to pay a great cost for this – it had to abandon many of the technological opportunities that foreign direct investors might have offered.

By adopting an outward-looking development strategy, the government drove Korean industries out into competitive international market, putting them under great pressure for technological learning and/or development. Korean industries responded to such pressures by investing heavily in technology development. By developing technological competence, they have been able to survive international competition, and establish world prominence in such high-technology areas as telecommunications, semi-conductor memory chips, LCD, automobiles, shipbuilding, and so on. Protectionist policy may be effective in creating initial market opportunities for domestic industries, but if such a policy is prolonged, industries will develop immunity against market pressure for innovation. It may be for this reason that export-oriented firms achieved technological learning more rapidly than import-substituting firms

Since the early 1960s, the government has played a key role in Korea's development. The government first initiated science and technology development as part of the national economic development plan, and has led the development, not just as a rule-setter but also as a target-setter as well as a financier. But as industrial development proceeds, it has become increasingly difficult for the government to intervene in economic as well as R&D activities because of the increased scale and complexity of industrial activities. Therefore, the pattern of government intervention in science and technology had to change from direct involvement as a target-setter

and commander-in-chief type leader to indirect involvement as a facilitator and promoter

In sum, Korea owes very much to its human resource and the outward-looking development strategy for the technological development and industrialization. Two major lessons from the Korean experiences are: First, human resource is the key to science and technology development and thus to economic growth, and second, nothing can better motivate private businesses to invest in technology development than market competition. But for Korea to sustain the past development into the future, it has to further strengthen basic scientific research capability and improve framework conditions for innovation, the core of which is competitive market.

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